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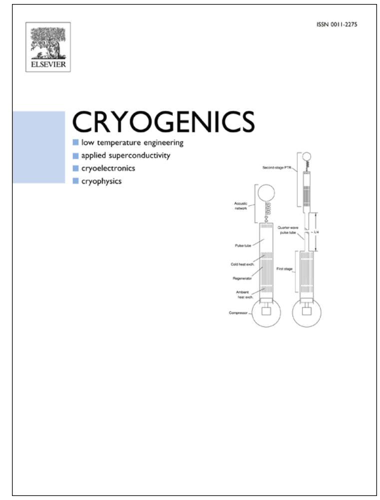

Research paper

The optimization on flow scheme of helium liquefier with genetic algorithm

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The optimization on flow scheme of helium liquefier with genetic algorithm

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Abstract:

There are several ways to organize the flow scheme of the helium liquefiers, such as arranging the expanders in parallel (reverse Brayton stage) or in series (modified Brayton stages). In this paper, the inlet mass flow and temperatures of expanders in Collins cycle are optimized using genetic algorithm (GA). Results show that maximum liquefaction rate can be obtained when the system is working at the optimal parameters. However, the reliability of the system is not well due to high wheel speed of the first turbine. Study shows that the scheme in which expanders are arranged in series with heat exchangers between them has higher operation reliability but lower plant efficiency when working at the same situation. Considering both liquefaction rate and system stability, another flow scheme is put forward hoping to solve the dilemma. The three configurations are compared from different aspects, they are respectively economic cost, heat exchanger size, system reliability and exergy efficiency. In addition, the effect of heat capacity ratio on heat transfer efficiency is discussed. A conclusion of choosing liquefier configuration is given in the end, which is meaningful for the optimal design of helium liquefier.

Key words: helium liquefaction, optimization, flow scheme, genetic algorithm

1. Introduction

It is known that the Collins cycle can satisfy the minimum configuration to acquire liquid helium (shown in Fig. 1(a)). Lots of work has been done by some authors before to improve the performance of Collins plant such as optimizing thermodynamic parameters and changing arrangements of all the work-heat transfer units. Rijo Jacob Thomas et al. studied on options of splitting and combining Brayton stages into modified Brayton stages and they are evaluated and compared by exergy analysis[1]. M. D. Atrey conducted a thermodynamic analysis on Collins plant at the condition of given efficiency of expanders and effectiveness of heat exchangers, whose results show that there exists an optimal mass flow through expanders to yield maximum liquid helium and minimum net input power[2]. Rijo Jacob Thomas et al. have studied the effects of splitting and combining Brayton stages in detail, whose results show that parallel expander arrangement has a higher rate of liquefaction than series arrangement by 10%-13% for two or three expanders[3]. At the same condition, Rijo Jacob Thomas has found that while 80% of the mass flow through compressors is equally diverted into two expanders in Collins system, the liquid output is maximum[4]. G.Cammarata et .al optimized an existing helium liquefaction system that works according to a Collins cycle using GA method[5]. The results of optimal parameters and existing study conclusions are all about Collins plant. There is almost no relative research on liquefaction cycle consists of modified Brayton stages (shown in Fig. 1(b)) as well as the different thermodynamic mechanism between these two schemes.

To ensure reliability of the liquefaction system, expander has to perform at a limited wheel speed, which is decided by the present manufacturing level and influenced by the inlet temperature, pressure drop as well as mass flow through it. The scheme in which expanders are arranged in series with heat exchangers between them has higher operation reliability for the pressure drop is divided by two expanders, but its plant efficiency is lower than that of Collins cycle's. High efficiency and good stability of a liquefaction plant are always expected, therefore another configuration is advised to achieve this purpose (shown in Fig. 1(c)). GA method is adopted to optimize the mass flow and the inlet temperatures of expanders on these schemes to reach largest liquefaction rate, making sure they are in the best working status. GA method is effective and easy to implement in searching solutions, there is no